Long-term postplacement cost after endovascular aneurysm repair

Robert E. Noll, Jr, MD,[a] **Britt H. Tonnessen, MD,**[a] **Krishna Mannava, MD,**[a] **Samuel R. Money, MD, MBA,**[b] and **W. Charles Sternbergh III, MD,**[a] *New Orleans, La; and Scottsdale, Ariz*

Background: **Previous studies have demonstrated that the initial hospital cost associated with endovascular aneurysm repair (EVAR) is approximately $20,000. However, the cost of long-term surveillance and secondary procedures is poorly characterized.**

Methods: **Between December 1998 and June 2006, 259 patients underwent EVAR for infrarenal aneurysms at a single institution. Follow-up costs were calculated using a relative value unit based hospital cost accounting system, which incorporates departmental direct and indirect costs. Institutional overhead costs were included using a conversion factor. Costs for professional services were determined by a cost-to-charge ratio, and outpatient visits were calculated with a time-based formula. Year 2006 costs were applied to prior years. To minimize costs associated with the early learning curve, the initial 50 EVAR patients between December 1995 and 1998 were excluded. Patients with <1 year follow-up were also excluded. Data are expressed as mean ± standard error.**

Results: **The mean follow-up after EVAR for 136 patients was 34.7 ± 1.8 months. The cumulative 5-year postplacement cost per patient was $11,351. The 27 patients (19.9%) who required secondary procedures had a 5-year cumulative cost of $31,696 compared with $3668 for 109 patients without secondary procedures (8.6-fold increase, *P* < .05). The 5-year cost for patients with endoleak was $26,739 compared with $5706 for those without endoleak (4.7-fold increase, *P* < .05). Overall, major cost components were 57.4% for secondary procedures and 32.5% for radiologic studies.**

Conclusions: **During a 5-year period, the postplacement cost of EVAR increases the global cost by 44%. The subgroups of patients with endoleaks and those requiring secondary procedures generate a disproportionate share of postplacement costs. Efforts at minimizing cost should emphasize technical and device modifications aimed at reducing endoleaks and the need for secondary procedures. (J Vasc Surg 2007;46:9-15.)**

Endovascular aneurysm repair (EVAR) offers the advantage of lower perioperative morbidity and mortality as well as shorter hospital stay and operative time compared with open repair.[1,2] Nationwide, these clinical benefits have translated into a trend, such that EVAR is often replacing open repair of infrarenal abdominal aortic aneurysms (AAA).[3] During the past decade, EVAR has evolved into the treatment of choice for elderly and high-risk patients but is also frequently used in lower-risk patients with suitable anatomy.

EVAR has not been proven to reduce cost, however. A number of cost-analysis studies have demonstrated that the initial cost of EVAR exceeds that of open repair, despite a shorter hospitalization and fewer early complications.[4-8] This is largely the result of high endograft device costs. Medicare reimbursement often fails to meet the hospital expenses of EVAR.[4,9] Hospitals and health care systems, already struggling with escalating costs, may find financial considerations further influencing their application of EVAR.

From the Section of Vascular Surgery, Ochsner Clinic Foundation[a]; and the Division of Vascular Surgery, Mayo Clinic Scottsdale.[b]

Competition of interest: none.

Presented at the Annual Meeting of the Southern Association for Vascular Surgery, Phoenix, Ariz, Jan 18-21, 2006.

Correspondence: W. Charles Sternbergh, III, MD, Section of Vascular Surgery, Ochsner Clinic Foundation, 1514 Jefferson Hwy, New Orleans, LA 70121 (e-mail: csternbergh@ochsner.org).

0741-5214/$32.00

doi:10.1016/j.jvs.2007.03.037

Despite many clinical benefits and widespread use, enthusiasm for EVAR is tempered by long-term problems of endoleak, migration, sac expansion, and even rupture. Vigilant, lifelong follow-up is important to identify and correct these complications. Rates of intervention for these technical and device-related failures have been up to 27%.[10-12] Open AAA repairs do not have the same requirements for long-term follow-up and require fewer late interventions for graft related complications.[13] As a result, the costs of EVAR may continue to accumulate over time compared with open AAA repair. The substantial costs associated with long-term surveillance and secondary procedures have not been well established. This study defines the long-term expenses of EVAR and characterizes the specific components and contributors to postplacement costs.

METHODS

Between December 1998 and June 2006, 259 consecutive patients underwent endovascular repair of infrarenal aortic aneurysms at the Ochsner Clinic Foundation (OCF). The first 50 patients, between December 1995 and 1998, were excluded from this analysis to minimize increased costs that could have been associated with the learning curve in this cohort. A prospective database of all EVARs at our institution has been maintained since 1997. This database was queried and supplemented with medical records to determine all radiologic studies, secondary procedures, hospital readmissions, and outpatient visits that occurred during the follow-up period. Thus, this is a retrospective review of our prospectively maintained database.

Our standard surveillance protocol after EVAR for all devices consists of an initial postoperative physical exam and outpatient visit at 2 weeks, followed by four-view plain abdominal radiographs (anteroposterior, lateral, 2 obliques), computed tomography (CT) scan of the abdomen and pelvis with 2.5-mm to 3-mm axial images, and additional outpatient visits at 1, 6, and 12 months, and yearly thereafter. Patients treated in United States Food and Drug Administration trials had no significant difference in surveillance protocol except some required an immediate postoperative CT. This CT was performed at the initial endograft placement and, therefore, the associated extra cost was excluded from this study. In patients with renal insufficiency, duplex ultrasonography is used in place of CT for endograft surveillance.

Late endovascular secondary procedures usually reset the follow-up timetable to 1, 6, 12 months, and yearly thereafter. Although additional diagnostic studies and follow-up were obtained at the discretion of the attending surgeon, the two attendings responsible for all of the implants (W. C. S., S. R. M.) closely followed the established surveillance protocol. To examine long-term costs, any patient with <1-year follow-up at OCF was excluded.

Cost analysis. Institutional costs incurred directly from patient care were accessed through OCF's cost accounting database (Eclipsys, Boca Raton, Fla). Costs of preoperative evaluation, and initial endograft placement with hospitalization, were not part of the present study.

The steps in our cost accounting system are briefly described here. Direct expenses are first consolidated monthly at a departmental (cost center) level and then are classified by the cost components of labor, supply, equipment, and facility. Next, components are divided into fixed expenses independent of patient volume and variable expenses dependent on patient volume. Individual patients are assigned cost codes for every chargeable service or supply item. Departmental managers and Hospital Decision Support then develop allocation statistics (relative value units) for each component of every cost code so that a final cost can be assigned. Individual patient costs are the sum of costs from each department utilized. The average cost calculations from January to June 2006 were used to adjust prior years' costs for the sake of data uniformity.

Professional fees were calculated by using department-specific cost-to-charge ratios and were adjusted according to the average January to June 2006 costs. Costs for outpatient appointments were determined by using a time-based formula. Patient appointments were categorized as 10, 20, and 30 minutes according to Evaluation and Management codes. Outpatient department expenses were then allocated by the time coded for the follow-up appointment.

Overhead costs for the institution were added to the direct costs by a factor of 30% for each patient. This factor has been uniformly decided on by Hospital Decision Support and varies 1% to 2% monthly. This method allows for equitable distribution among patients: those patients with higher overall cost absorb more overhead cost. Overhead expense includes costs from departments not directly involved in patient care (eg, housekeeping, computer technology, finance), equipment and facility depreciation, and interest expense on borrowings.

All costs incurred after discharge from the original EVAR were included in this study and will heretofore be referred to as *postplacement* costs. These postplacement costs were subdivided into outpatient visits, radiologic studies, laboratory tests, secondary procedures, and hospital readmissions for complications of EVAR that did not require a secondary procedure (eg, ischemic colitis). Radiologic costs consisted of CT scans, abdominal radiographs, duplex ultrasonography, and vascular laboratory studies.

A secondary procedure was defined as any intervention (including diagnostic angiograms) performed due to the original aneurysm or for a complication of EVAR during the follow-up period. Secondary procedure costs were further broken down into cost of operating/interventional suite (anesthesia, operating room time, professional fees, nonendovascular surgical supply), endovascular supply, room and board (recovery room, outpatient surgery, floor/intensive care), pharmacy/laboratory, medical supply (nonoperative supply costs), radiology, and miscellaneous (respiratory care, dialysis, physical therapy, occupational therapy).

Endoleak was defined as persistent blood flow outside the endograft identified on an imaging study during follow-up. The types of endoleak have been previously reported.[14,15] Indications for secondary interventions for endoleak were the presence of a type I or type III endoleak, or a type II endoleak with significant aneurysm sac expansion (>5 mm). Translumbar glue embolization has been favored for treatment of type II endoleaks in recent years, although previously coil microembolization was used. Migration was determined as ≥10-mm caudal movement of the endograft or any amount of migration resulting in symptoms or a secondary procedure.

Statistical analysis. The data are expressed as mean ± standard error. Cost comparisons between groups with and without secondary interventions or endoleaks were made with the Wilcoxon two-sample test. $P < .05$ was considered statistically significant. Statistical analysis was performed by using SAS 8.2 software (SAS Institute Inc, Cary, NC).

RESULTS

Patient cohort. Of 259 completed EVARs included in the study period, 136 patients were included in the final cost analysis. Reasons for exclusion were death in 35 patients, <1 year since EVAR in 33, 28 were lost to follow-up, 15 had follow-up at another institution, and 12 patients refused further treatment.

Complete follow-up with all required outpatient visits and surveillance imaging was attained in 61 of the 136 included patients. An additional 60 patients missed one or more outpatient visits or imaging studies during their follow-up period, completing 81.1% of outpatient visits, 75.9% CT or duplex ultrasonography, and 75.1% of abdominal radiograph sets. The remaining 15 patients had an interval of ≥1

Table I. Five-year cumulative postplacement cost

Follow-up year	All patients* No.	All patients* Mean cost	No secondary procedure* No.	No secondary procedure* Mean cost	Secondary procedure* No.	Secondary procedure* Mean cost
1	136	\$2768 ± \$556	109	\$1635 ± \$131	27	\$7340 ± \$2608†
2	98	\$1435 ± \$428	75	\$499 ± \$21	23	\$4490 ± \$1695†
3	65	\$2205 ± \$706	47	\$458 ± \$25	18	\$6767 ± \$2254
4	47	\$1710 ± \$610	33	\$523 ± \$52	14	\$4506 ± \$1884†
5	33	\$3233 ± \$1687	22	\$553 ± \$77	11	\$8593 ± \$4796
Cumulative cost		\$11,351		\$3668		\$31,696†

*Data are mean ± standard error.
†Statistically significant ($P < .05$) vs no secondary intervention group.

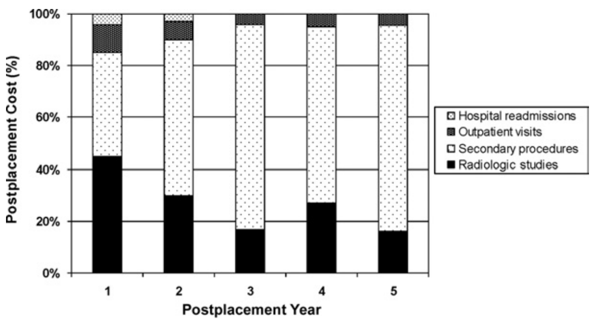

Fig 1. Yearly postplacement cost components. Laboratory costs were <0.6% for all years.

years (mean 1.3 ± 0.2 years) without follow-up, after which they resumed normal surveillance.

Baseline characteristics. The mean age of the patients (87.5% men) was 73.2 ± 0.6 years. Comorbidities included the presence of coronary artery disease (58.8%), hypertension (57.4%), peripheral vascular disease (30.1%), chronic obstructive pulmonary disease (27.9%), diabetes mellitus (13.9%), and chronic renal insufficiency (12.5%). Spinal/regional anesthesia was used in 80.9% of EVAR.

Modular bifurcated endografts were deployed in 130 patients. Endograft types were Zenith (Cook, Bloomington, Ind) in 75, AneuRx (Medtronic/AVE Inc, Santa Rosa, Calif) in 50, and Excluder (W.L. Gore & Assoc, Flagstaff, Ariz) in five. The other six patients were treated with endocuffs (AneuRx, n = 5; Zenith, n = 1) alone for saccular aneurysms (n = 4) and pseudoaneurysms (n = 2).

Postplacement costs. The mean follow-up was 34.7 ± 1.8 months. During the first postplacement year, patients averaged 3.7 ± 0.1 outpatient visits, 2.7 ± 0.1 CT scans, and 2.5 ± 0.1 complete sets of abdominal radiographs. For the subsequent years 2 through 5 of follow-up, the number of yearly outpatient visits, CT scans, and abdominal radiograph sets averaged 1.2 ± 0.04, 1.0 ± 0.04, and 1.0 ± 0.03, respectively. Ultrasound studies (n = 18) were used selectively in place of surveillance CT scans in 10 patients with renal insufficiency.

Mean postplacement cost was \$2768 ± \$556, \$1435 ± \$428, \$2205 ± \$706, \$1710 ± \$610, and \$3233 ± \$1687 at 1, 2, 3, 4, and 5 years, respectively. Overall, the cumulative 5-year cost per patient was \$11,351 (Table I). Postplacement cost consisted of secondary procedures (57.4%), radiologic studies (32.5%), outpatient visits (7.6%), related hospital readmissions (2.1%), and laboratory costs (0.4%). In the first year of follow-up, the largest cost component was radiologic studies (Fig 1). For years 2, 3, 4, and 5, secondary procedures accounted for most of the expenses.

Table II. Secondary procedures

Procedure	No.	Mean cost*
Endograft explant/EAB†	2	\$57,681 ± \$6464
Iliac limb placement/EC‡	1	\$29,479
Open conversion (delayed)	4	\$21,382 ± \$3130
Aortouniiliac device	1	\$20,983
Iliac endocuff	6	\$13,042 ± \$2274
Endocuff	4	\$8722 ± \$2041
Femoral-femoral bypass	1	\$8217
Laparoscopic IMA ligation	1	\$8021
Thrombolysis	1	\$7437
PTA ± stent	2	\$5153 ± \$334
Translumbar glue embolization	3	\$4850 ± \$769
Coil microembolization	4	\$4640 ± \$458
Diagnostic angiogram	20	\$2677 ± \$378
Abscess drainage	1	\$1507

EAB, Extra-anatomic bypass; *EC,* endocuff; *IMA,* inferior mesenteric artery; *PTA,* percutaneous transluminal angioplasty.
*Data are mean ± standard error.
†One procedure was staged, with the costs of both procedures combined.
‡Staged placement of iliac limb after the initial endograft device malfunctioned.

Secondary procedures. Fifty-one secondary procedures were performed in 27 patients (19.9%; Table II). The mean time to secondary procedures was 25.4 ± 1.0 months. Patients who underwent a secondary procedure at any point during follow-up were also analyzed as a separate group. Patients with secondary procedures had an 8.6-fold increase in postplacement cost (Table I) compared with patients not needing an additional intervention ($P < .05$). Cost components for secondary procedures were operating/interventional suite (41.1%), room and board (21.1%), endovascular supply (18.2%), pharmacy/laboratory (10.2%), medical supply (3.0%), radiology (1.5%), and miscellaneous (4.9%).

The most common secondary procedure was a diagnostic angiogram (n = 20), performed in 13 patients (Fig 2, *A*).

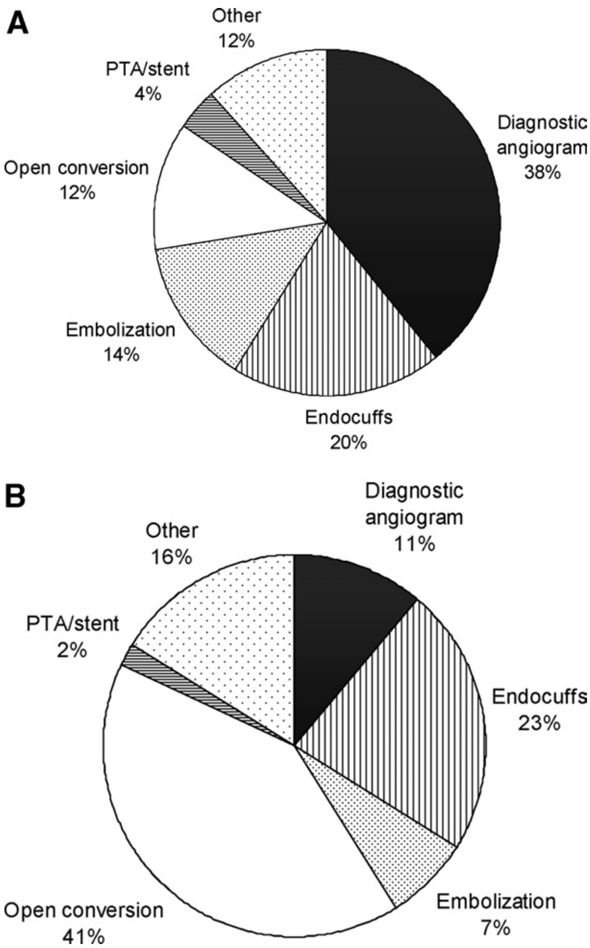

Fig 2. **A,** Secondary procedures by frequency (%). **B,** Secondary procedures by cost (%). *PTA,* Percutaneous transluminal angioplasty.

Indications for these angiograms were aneurysm growth (n = 13), endoleak identification (n = 6), and endograft limb thrombosis (n = 1; Table III). The remaining 31 secondary procedures were performed for therapeutic reasons (Table II). Proximal (n = 4) and iliac (n = 6) endocuffs were placed for cases of endoleak (n = 6), migration (n = 2), or both endoleak/migration (n = 2). The mean cost of an iliac endocuff procedure was \$13,042 ± \$2274 compared with \$8722 ± \$2041 for a proximal endocuff procedure. The use of additional supplies with iliac endocuffs was responsible for the increased expense of this procedure.

Six delayed open conversions were required. Conversions were due to endoleaks alone (type I, type III) in 2 patients, for endograft infection in 2, migration and endoleak (type I) in 1, and aneurysm expansion (endotension) in 1. Both open conversions for infection were managed with extra-anatomic bypass and endograft explantation. The mean cost of open conversion alone was \$21,382 ± \$3130, and the mean cost for open conversion with extra-anatomic bypass was \$57,681 ± \$6464, the highest for any of the secondary procedures. These six conversions accounted for 41% of the secondary procedure expense (Fig 2, *B*).

Table III. Diagnostic angiograms

Patient	*Indications*	*Findings*	*Additional treatment*
1	AAA growth	None	
	AAA growth	None	
	AAA growth	None	Delayed OC
2	EL identification	None	None
3	Endograft limb thrombosis	Limb occlusion	Femorofemoral bypass
4	AAA growth	Type II EL	None
5	EL identification	Type I EL	EC
6	AAA growth	Type II EL	Embolization
7	AAA growth	None	Delayed OC
8	AAA growth	None	
	AAA growth	None	Delayed OC
9	EL identification	Type II EL	Embolization
10	AAA growth	Type II EL	Embolization
	AAA growth	Type III EL	Iliac endocuff
11	AAA growth	None	Iliac endocuff
	AAA growth	None	
	AAA growth	Infection	Endograft explant/ EAB
12	EL identification	Type II EL	
	EL identification/ attempted embolization	Type II EL	Laparoscopic IMA ligation
13	EL identification	Type II EL	Embolization

AAA, Abdominal aortic aneurysm; *OC,* open conversion; *EL,* endoleak; *EC,* endocuff; *IMA,* inferior mesenteric artery; *EAB,* extra-anatomic bypass.

Related hospital admissions. Two patients required a hospital readmission not associated with a secondary procedure. One was admitted for ischemic colitis 5 days after EVAR. The colitis resolved without operative intervention, and the patient was discharged on hospital day 8 for a total cost of \$12,264. The other patient was admitted on two separate occasions with incisional postoperative wound infections. The first occurred after EVAR and the second after a delayed open conversion. The patient was released from the hospital in good condition on both occasions, with respective readmission costs of \$1979 and \$3650.

Endoleaks. During the follow-up period, 27 patients (19.9%) had 29 endoleaks (type I, n = 5; type II, n = 17; type III, n = 7). In 14 patients, 14 endoleaks were seen on the 1-month postplacement CT; the remaining 15 endoleaks were detected later in follow-up. Eight endoleaks (type II) were monitored without any secondary procedure, and seven have resolved to date at a mean of 7.7 ± 1.1 months. In patients with endoleaks, 5-year cumulative post-placement costs were 4.7-fold higher (Table IV) than for patients without endoleak (\$26,739 vs \$5706; $P < .05$).

DISCUSSION

In 2000, OCF reported a greater hospital cost for EVAR (\$19,985) than open AAA repair (\$12,546).[4] For

Table IV. Postplacement costs in patients with no endoleak versus patients with endoleak

	*Patients with no endoleak**		*Patients with endoleak**	
Follow-up year	*No.*	*Mean cost*	*No.*	*Mean cost*
1	109	$2297 ± $615	27	$4668 ± $1253†
2	77	$569 ± $74	21	$4607 ± $1851
3	50	$1715 ± $698	15	$3836 ± $1986
4	35	$567 ± $59	12	$5043 ± $2171
5	22	$558 ± $77	11	$8585 ± $4797
Cumulative cost		$5706		$26,739†

*Data are mean ± standard error.
†Statistically significant ($P < .05$) vs no endoleak group.

the most part, the disparity between these costs was due to the high cost of the device, which accounted for >50% of total hospital expense. Similarly, others[5-8] have also found that the initial cost of EVAR exceeds that of open repair. Any potential financial advantage of EVAR from reduced length of stay or decreased perioperative morbidity is therefore eliminated by the device cost. Hopeful expectation that device costs would decrease after widespread adoption of EVAR and increased competition has yielded to realistic acknowledgement of persistently high and escalating device costs.

The present study demonstrates that the $11,351 postplacement cost of EVAR during a 5-year period increases the global cost by 44% when added to the $19,985 implantation cost[4] converted to 2006 dollars.[16] The largest driver of these costs was secondary procedures, accounting for 57.4% of the total postplacement costs. Patients who required a secondary procedure had an 8.6-fold increase in 5-year cumulative mean cost of $31,696 compared with $3668 for those who did not. In those patients without secondary procedures, their 5-year cost ($3668) increased the global cost by only 14%. Patients with an endoleak had 5-year postplacement costs that were 4.7-fold higher than those with no endoleak ($26,739 vs $5706). As such, the most effective way to reduce postplacement cost would be to minimize the need for secondary procedures.

Over time, the postplacement costs for EVAR accumulate, largely as a result of vigilant monitoring and late secondary procedures. Few studies,[17-20] however, have investigated the postplacement expense for EVAR. Prinssen et al[17] studied 77 patients after EVAR performed primarily with the Ancure device, with mean follow-up of 19.9 months. Cost of follow-up was estimated from procedural costs in the literature and the authors' frequency of surveillance and secondary procedures. Their estimated postplacement costs were $3631 at 1 year and $9729 at 5 years. An Australian series[18] examined all follow-up costs in 54 patients with a median 12 months' follow-up. After conversion to US dollars, average postplacement cost was $999 per year.

The results of our current study parallel those of the previous studies but also add significantly to the understanding of long-term cost. Our cumulative cost was $2768 at 1 year and $11,351 at 5 years, similar to the findings of Prinnsen et al.[17] The higher cost in our study compared with the Hayter et al[18] study likely relates to our longer follow-up (mean, 34.7 months) and the larger number of patients. We captured a large number of costly late secondary procedures, 43% (n = 22) of which occurred 3 to 5 years postplacement. In addition, higher overhead costs in the United States may be a factor.[21]

Secondary procedures. A secondary procedure was required in 19.9% of the cohort (n = 27), and open conversions were necessary in 4.4% (n = 6). These values are within the range reported in recent literature, with rates as high as 27% for secondary procedures and 9% for open conversion.[11,17] In addition, to capture all costs, we counted diagnostic angiograms as secondary procedures, which is not uniformly done in the published reports. Similarly, our 19.9% incidence of endoleaks corresponds with previously reported values.[22,23] These comparable results confirm that the frequency of our largest cost generators is representative of the general post-EVAR population.

Endoleaks alone or in conjunction with migration were the driving force behind 56.9% of the secondary interventions (n = 29). Significant differences in long-term follow-up cost between patients with and without secondary intervention ($31,696 vs $3668) and endoleak ($26,739 vs $5706) stress the monetary impact of late complications. Costly late conversions comprised 12% of secondary procedures yet accounted for 41% of late expense (Fig 2). The procedural components, operative/interventional suite, and endovascular materials generated 59.3% of cost of the secondary procedures.

Radiologic studies. Diagnostic radiologic studies for endograft surveillance were responsible for >30% of the long-term follow-up expense and comprised the second largest cost component. Although surveillance schedules vary, our protocol is a common one. Our 2006 costs were $350 for a CT of the abdomen and pelvis, $70 for duplex ultrasound imaging, and $51 for four-view abdominal radiographs. Although the cost per study is not large, expenses accumulate rapidly due to volume. A decrease in the frequency of postplacement CT or use of a different modality could reduce this large radiology expense. However, safe minimization of post-EVAR imaging will first require a reduction in complications and secondary interventions. Alternative methods of postprocedure monitoring provide another avenue for cost reduction.

Although color flow duplex ultrasound lacks the sensitivity of CT in endoleak detection,[24] contrast-enhanced ultrasound imaging may provide improved detection.[25] Unfortunately, the expense of ultrasound contrast agents and the inability to evaluate migration potentially limits its use. Remaining cost components contributed 10.1% of the total follow-up expense. The largest of these, outpatient visits (7.6%), coincided with the frequency of surveillance imaging.

It is apparent that long-term follow-up adds considerable expense to the global hospital cost of EVAR. However, this does not mean EVAR lacks societal cost-effectiveness. Patel et al,[26] and Bosch et al,[27] using Markov decision analysis models, found EVAR to be a cost-effective alternative to open repair. Both of these analyses included cost of follow-up. Critical to societal cost-effectiveness is maintenance of low morbidity and mortality rates[26] and long-term failure and rupture rates.[27]

Study limitations. This study has certain limitations. First, most patients did not have complete follow-up in which all outpatient visits and surveillance imaging occurred according to the strict surveillance protocol. Therefore, the calculated cost does not reflect all of the potential postplacement expenses that could be incurred in a "model" patient. Our data more accurately represent a realistic cross-section of postplacement follow-up, and therefore, our determined costs are potentially less than those obtained when follow-up is complete.

Second, the absence of those patients lost to follow-up should not affect the results. All costs were given as per patient with follow-up. Thus, there should be no change in mean per patient costs, unless those patients had a different postplacement history.

As a single institution costing analysis, costs such as overhead and labor may vary regionally or be hospital specific. As a retrospective study, follow-up practice patterns and expenses included in the early experience with endografts, such as surveillance ankle-brachial indices, are no longer used. As a consequence, current yearly postplacement costs are potentially lower. It is also possible that our use of diagnostic angiograms was more aggressive in our earlier experience. Nonetheless, most angiograms yielded a positive result, and furthermore, with exclusion of the first 50 patients in our series, it is unlikely that a learning curve issue was a significant factor in the cost differences. Our study did not compare long-term postplacement costs of EVAR with open repair. Follow-up costs of open repair may be less, as late graft-related complications are less frequent[13] and long-term surveillance is not typically required.

Finally, there are limitations to the cost data. The assigned institutional overhead cost factor is an estimated fluctuating value that varies a percentage or two monthly. In addition, the cost of professional fees was determined by using a cost-to-charge ratio. Although this is a well-characterized method of estimating costs, it is ultimately based on charges, not underlying cost. These potential areas of subtle cost alterations are unlikely to have affected the larger trends and values seen in our cost analysis.

CONCLUSION

Long-term postplacement costs increase the global cost of EVAR by 44% during a 5-year period. Secondary procedures have the greatest impact on this cost, and when combined with surveillance imaging expenses, account for 89.9% of postplacement cost. A disproportionate amount of postplacement expense results from the subgroups of patients with secondary procedures or endoleaks. Long-term postplacement costs will continue to increase with continued surveillance and treatment for late complications such as endoleak and migration. To minimize postplacement costs, efforts should be directed to the device and technical modifications that will decrease endoleaks and the need for secondary procedures.

We thank Kurt Wootan, BS, with Hospital Decision Support for assistance with financial data and Xiaozhang Jiang, MS, for the statistical analysis.

AUTHOR CONTRIBUTIONS

Conception and design: RN, BT, KM, SM, WS
Analysis and interpretation: RN, BT, KM, SM, WS
Data collection: RN
Writing the article: RN, BT
Critical revision of the article: RN, BT, KM, SM, WS
Final approval of the article: RN, BT, KM, SM, WS
Statistical analysis: RN
Obtained funding: BT, SM, WS
Overall responsibility: WS

REFERENCES

1. Prinssen M, Verhoeven EL, Buth J, Cuypers PW, van Sambeck MR, Balm R, et al. Dutch Randomized Endovascular Aneurysm Management (DREAM) Trial Group. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. N Engl J Med 2004;351:1607-18.
2. Greenhalgh RM, Brown LC, Kwong GP, Powell JT, Thompson SG. EVAR trial participants. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomized controlled trial. Lancet 2004;364:843-8.
3. Dillavou ED, Muluk SC, Makaroun MS. Improving aneurysm-related outcomes: nationwide benefits of endovascular repair. J Vasc Surg 2006;43:446-52.
4. Sternbergh WC III, Money SR. Hospital cost of endovascular versus open surgical repair of abdominal aortic aneurysms: a multicenter study. J Vasc Surg 2000;31:237-44.
5. Clair DG, Gray B, O'Hara PJ, Ouriel K. An evaluation of the costs to health care institutions of endovascular aortic aneurysm repair. J Vasc Surg 2000;32:148-52.
6. Bosch JL, Lester JS, McMahon PM, Beinfeld MT, Halpern EF, Kaufman JA, et al. Hospital costs for elective endovascular and surgical repairs of infrarenal abdominal aortic aneurysms. Radiology 2001;220: 492-7.
7. Dryjski M, O'Brien-Irr MS, Hassett J. Hospital costs for endovascular and open repair of abdominal aortic aneurysm. J Am Coll Surg 2003; 197:64-70.
8. Angle N, Dorafshar AH, Moore WS, Quinones-Baldrich WJ, Gelabert HA, Ahn SS, et al. Open versus endovascular repair of abdominal aortic aneurysms: what does each really cost? Ann Vasc Surg 2004;18:612-8.
9. Bertges DJ, Zwolak RM, Deaton DH, Teigen C, Tapper S, Koslow AR, et al. Current hospital costs and Medicare reimbursement for endovascular abdominal aortic aneurysm repair. J Vasc Surg 2003;37:272-9.
10. Conners MS III, Sternbergh WC III, Carter G, Tonnessen BH, Yoselevitz M, Money SR. Secondary procedures after endovascular aortic aneurysm repair. J Vasc Surg 2002;36:992-6.
11. Becquemin J, Kelley L, Zubiliewicz T, Desgranges P, Lapeyre M, Kobeiter H. Outcomes of secondary interventions after abdominal aortic aneurysm endovascular repair. J Vasc Surg 2004;39:298-305.
12. Laheij RJ, Buth J, Harris PL, Moll FL, Stelter WJ, Verhoeven EL. Need for secondary interventions after endovascular repair of abdominal aortic aneurysms. Intermediate-term follow-up results of a European collaborative registry (EUROSTAR). Br J Surg 2000;87:1666-73.

13. Hallett JW, Marshall DM, Petterson TM, Gray DT, Bower TC, Cherry KJ Jr, et al. Graft related complications after abdominal aortic aneurysm repair: reassurance from a 36 year population based experience. J Vasc Surg 1997;25:277-84.
14. White GH, May J, Waugh RC, Yu W. Type I and type II endoleak: a more useful classification for reporting results of endoluminal AAA repair [Letter]. J Endovasc Surg 1998;5:189-91.
15. White GH, May J, Waugh RC, Chaufour X, Yu W. Type III and IV endoleak: toward a complete definition of blood flow in the sac after endoluminal AAA repair. J Endovasc Surg 1998;5:305-9.
16. United States Bureau of Labor Statistics Web site. Available at URL: http://www.bls.gov/cpi/. Accessed Jan 12, 2007.
17. Prinssen M, Wixon CL, Buskens E, Blankensteijn JD. Surveillance after endovascular aneurysm repair: diagnostics, complications, and associated costs. Ann Vasc Surg 2004;18:421-7.
18. Hayter CL, Bradshaw SR, Allen RJ, Guduguntla M, Hardman DTA. Follow-up costs increase the cost disparity between endovascular and open abdominal aortic aneurysm repair. J Vasc Surg 2005;42:912-8.
19. Forbes TL, DeRose G, Kribs S, Harris KA. A cost-effectiveness analysis of standard versus endovascular abdominal aortic aneurysm repair. Can J Surg 2002;45:420-4.
20. Birch SE, Stary DR, Scott AR. Cost of endovascular versus open surgical repair of abdominal aortic aneurysms. Aust N Z J Surg 2000;70:660-6.
21. Brox AC, Filion KB, Zhang X, Pilote L, Obrand D, Haider S, et al. In-hospital cost of abdominal aortic aneurysm repair in Canada and the United States. Arch Intern Med 2003;163:2500-4.
22. Marrewijk C, Buth J, Harris PL, Norgren L, Nevelsteen A, Wyatt MG. Significance of endoleaks after endovascular repair of abdominal aortic aneurysms: the EUROSTAR experience. J Vasc Surg 2002;35:461-73.
23. Ouriel K, Clair DG, Greenberg RK, Lyden SP, O'Hara PJ, Sarac TP, et al. Endovascular repair of abdominal aortic aneurysms: device-specific outcome. J Vasc Surg 2003;37:991-8.
24. Raman KG, Missig-Carroll N, Richardson T, Muluk SC, Makaroun MS. Color-flow duplex ultrasound scan versus computed tomographic scan in the surveillance of endovascular aneurysm repair. J Vasc Surg 2003;38:645-51.
25. Henao EA, Hodge MD, Felkai DD, McCollum CH, Noon GP, Lin PH, et al. Contrast-enhanced Duplex surveillance after endovascular abdominal aortic aneurysm repair: improved efficacy using a continuous infusion technique. J Vasc Surg 2006;43:259-64.
26. Patel ST, Haser PB, Bush HL, Jr, Kent KC. The cost-effectiveness of endovascular repair versus open surgical repair of abdominal aortic aneurysms: a decision analysis model. J Vasc Surg 1999;29:958-71.
27. Bosch JL, Kaufman JA, Beinfeld MT, Adriaensen ME, Brewster DC, Gazelle GS. Abdominal aortic aneurysms: cost-effectiveness of elective endovascular and open surgical repair. Radiology 2002;225:337-44.

Submitted Jan 28, 2007; accepted Mar 6, 2007.

INVITED COMMENTARY

Ronald L. Dalman, MD, *Stanford, Calif*

This report constitutes a best-guess snapshot of costs incurred during the rapid evolution of practice norms for endovascular aneurysm repair (EVAR) placement and follow-up. Averaging costs for postoperative protocol compliance between 1999 and 2006, given multiple device upgrades, steady improvement in computed tomography (CT)-based image quality (20 catheter-based angiograms were performed for endoleak analysis in this study), better understanding of the significance and natural history of type II endoleaks, and better options for secondary intervention (eg, CT-guided glue or thrombin injection) is misleading and likely overestimates the essential underlying cost of contemporary long term EVAR patient management. The first 50 patients in the Ochsner EVAR practice were excluded to minimize the cost impact of the steep initial phase of the procedural learning curve; given their protean manifestations, the endoleak management learning curve, while flatter, is undeniably longer. And, even prospectively acquired data does not lend itself well to standardization during retrospective analysis (eg, "additional studies were left to the discretion of the individual surgeon"). Nearly half of the patients did not complete follow-up as requested. What were the clinical consequences of these missed visits? What would it have cost to have all 136 patients achieve recommended endpoints? Is it possible that less rigorous follow-up for all patients would have provided comparable outcomes at lower cost? Across the country, secondary intervention rates are decreasing despite increasingly aggressive EVAR patient selection. While critically important to the future of surgical abdominal aortic aneurysm management, the challenge inherent in this analysis is the evolutionary nature of EVAR and the applicability of historical cost data to contemporary practice.